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Performance Standards for Greenhouse Gas (GHG) Projects

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1. Introduction

Climate change mitigation projects that reduce greenhouse gas (GHG) emissions are in the early stages of implementation in the energy use and supply, landfill gas, and land-use sectors.[1] In order to estimate GHG reductions, a project's emissions are compared to the performance of similar activities or services that represent the emissions that would be expected in the absence of the project.

Such mitigation projects are being advanced and considered under various state, national and international schemes. For example, the U.S. Department of Energy (U.S. DOE) is in the process of revisiting its reporting guidelines for the Voluntary Greenhouse Gas Reporting Program in an effort to improve its capacity to estimate reduced or avoided GHG emissions (U.S. DOE 2003). The U.S. Environmental Protection Agency (U.S. EPA) is looking at adopting guidelines for its Climate Leaders program for organizations that agree to meet GHG reduction targets. The World Resources Institute and the World Business Council for Sustainable Development have been working together to develop methods for estimating project-level GHG savings that could serve as an internationally accepted protocol. In addition, bilateral and international programs such as the Clean Development Mechanism, the Dutch government's Certified Emission Reduction Unit Procurement Tender, the Prototype Carbon Fund, and other preliminary carbon trading programs have provided guidelines for calculating avoided greenhouse gas emissions from mitigation projects. Several states in the U.S. are also developing climate change mitigation programs that include project opportunities.

Although administrative bodies responsible for these programs are exploring ways to bring greater rigor and uniformity in approach, to date there has been little consistency to the methodologies used for estimating baseline emissions. Regardless of the exact method used, the process of setting GHG baselines involves an examination of similar recent activities in the particular sector and within the relevant spatial boundary. The process of setting baselines for retrofit or replacement projects is different from that for new or “greenfield” projects. In the former case, the technology[2] being replaced or retrofitted is already in place, and its GHG performance can be measured and monitored.[3,4] For a “greenfield” project, however, a counterfactual baseline needs to be established, and its GHG performance needs to be estimated.

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[1] Offset projects are those that offset an entity’s greenhouse gas (GHG) emissions at another place, are confined to a specific geographic location, time period and institutional framework so as to allow changes in GHG emissions attributable to the project to be monitored and verified.

[2] We use the term technology broadly to mean both hardware and/or practices.

[3] Whether the retrofit or replacement itself meets other eligibility requirements is a separate question. Once eligibility has been established, the performance of the retrofit or replacement need only be compared to the previous performance to calculate emission reductions, at least until such time as the technological change were likely to have occurred anyway. From that point on, GHG reductions would need to be estimated using baselines.

[4] This assumes that the output of the activity remains unchanged. If the capacity increases as a result of the retrofit, the additional capacity should be compared to a baseline based on recent capacity additions since the additional capacity can be assumed to offset the need for another greenfield project.

The approach described here estimates emissions reductions by comparing the emissions rate of projects to the expected average emissions rate of similar relevant activities that provide the same output or services (such as power stations, industrial plants, or commercial buildings).[5] These activities are referred as “reference activities” and are used to help establish project baselines. One approach to estimating the expected average emissions rate is to examine activities that have recently come into operation and use the emissions from those activities to set a performance standard (defined as GHG emissions per unit of project output or service) to which the project will be compared.

Four steps are used in the performance standard-setting process for GHG mitigation projects. First, the project must be clearly defined so that relevant reference activities delivering the same service or output may be identified. The more clearly a project is defined the more narrowly appropriate reference activities may be selected. Second, the universe of reference activities may need to be restricted to those that lie within a certain spatial boundary. The spatial limitation becomes necessary where fuels and technologies that are available to accomplish a given reference activity are specific to a given political, socioeconomic, or physical boundary, or to an agro-ecological zone for land use projects.

Third, the set of reference activities may need to be restricted to those recent enough to be reasonably representative of the activities that a mitigation project is most likely to offset. Because energy conversion technologies, processes, and fuel sources are continually changing, a manufacturing facility constructed decades ago may not provide a reasonable estimate of the emissions that a current project will offset. Thus, it will frequently be necessary to restrict the temporal period of reference activities so that they clearly represent a plausible set of relevant reference alternatives.

Finally, when the set of relevant reference activities is selected, an average (or better than average) GHG emissions rate must be calculated to define the baseline GHG performance standard. This consists simply of the total emissions from the reference activities in a given year divided by their total output. The performance standard could then be set to reflect an emissions rate that is significantly better than average (e.g., top 25th percentile).

What criteria should be used to select the appropriate reference technologies, spatial boundary, and temporal periods of the reference activities?[6] We address the issue of setting appropriate spatial boundaries and temporal periods for reference activities, but we do not address the issue of defining appropriate reference activities in this paper. We use examples from the electric power and land use change and forestry (LUCF) sectors in order to illustrate the setting of spatial boundaries and temporal periods in Sections 2 and 3 respectively, however, the concepts would also apply to other sectors and project types.

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[5] In this paper we refer to emissions rates, but the concepts described herein can be applied to baseline methodologies that estimate absolute emissions.

[6] The performance standards discussed here are not intended to determine additionality, where national policies or circumstances may affect the likelihood of a project occurring in the reference case. Rather, these criteria are to be applied to reference case activities for projects for which eligibility screening (if applicable) has already been conducted. Thus, the performance standards derived may comprise a part of the eligibility screening process, but are not themselves sufficient to demonstrate additionality.

2. Setting the Spatial Boundaries of Reference Activities

Once a project has been classified by type, the first decision that needs to be made is how to delimit the spatial boundary of relevant activities to include in the reference set. Broadly speaking, two types of factors lead to differentiation of reference activities: physical and anthropogenic. Physical factors may be climatic (average temperatures, average rainfall) or geological (mix of resources available to construct or power a project activity, altitude, latitude, soil type). Anthropogenic sources of variation include sociocultural factors such as social norms, traditions, individual habits, attitudes, values, vested interests, and human capital, as well as economic factors such as household incomes, energy and other factor prices, employment, imperfect markets, financing, demand for specific services, and infrastructure considerations. National and international policies and programs also influence the above factors affecting the selection and application of technologies in a geographic area. Based on these considerations, we divide the spatial boundary into five broad categories: global; national boundaries and other administrative regions; infrastructure; biophysical (transboundary) region; and generic.

2.1.1 Global

We begin by focusing on reference activities that are essentially global in nature. By global in nature, we mean activities that consist of a mature technology or practice that is similar across regions or is rapidly converging. In these cases, there may truly be one global GHG performance standard that applies for all reference activities. For example, in some highly capital-intensive industrial sectors, technologies may be largely internationally standardized with relatively few designs being manufactured globally and little if any differentiation occurring regionally, nationally or locally. Thus, baseline technologies may be the same across the globe, although the energy and/or emissions performance standards may vary by the type of fuel burned in these technologies[7].

2.1.2 National Boundaries and Other Administrative Regions

For projects whose reference activities vary due primarily to anthropogenic factors, such as the installation of new technologies, the appropriate spatial boundary will generally correspond to some administrative boundary. This is due primarily to the influence of policies[8] on the choices and uses of technologies that emit GHGs, however, the availability of resources also has an effect. Economic, regulatory and infrastructure policies are likely to particularly affect the energy and industry sectors, and less so sectors that deal with animals, biomass or land use change.

The primacy of national policies in governing technology, fuels, and other aspects of human activity suggest that national scopes will generally be appropriate. Import restrictions (whether tariffs, quotas, or bans) affect the technologies or fuels available to consumers and domestic industries. In developing countries, restrictions on the import of consumer goods

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[7] In this case, fuel-specific global standards would be set rather than a single global technology standard.

[8] The term, policies, is intended to include government programs and other activities that influence GHG performance standards.

may serve to protect domestic industries, whose production processes are frequently less efficient than international standards among more developed countries. Producers in severely capital-constrained countries may often import used equipment, and this would need to be factored into the performance standards for those countries. Other policies may differentiate among fuels or technologies through taxes or subsidies, or through voluntary energy performance standards.[9]

Regional GHG performance standards may be warranted where common policies, and/or regional product supply networks exist. These may be either within a nation or span across countries. Common policies, rules or regulations are one reason for having a common baseline across a region. A state or province may have particular fuel availability or use, siting, or environmental restrictions that would dictate the choice of a technology. Minimum market penetration levels for renewable energy or energy efficiency technologies in certain states in the US affect the baseline for electric power or transportation projects. An economic community or trade bloc could also have similar restrictions on relevant technologies. A common European Union policy on appliance standards, for example, would affect the baseline for these goods. A program administrator would need to consider the relevant policies of all of the administrative regions having some jurisdiction or influence over the project site in order to determine which spatial boundary best defines the appropriate reference set of activities.

Tightly integrated product markets might require baselines that include the integrated market region. For example, a cement plant in Guatemala may offset a plant that could have been built anywhere in Central America or southern Mexico. Since many product markets are global, baselines for such projects would have to carefully evaluate the extent to which the project output could have been supplied by other sources that are located far away.

2.1.3 Infrastructure

Another reason for having a regional GHG performance standard is the extent of the physical infrastructure for supplying electricity and fuels or other products and services. The most common example applies to the spatial boundary used for new power plants, i.e., the extent of the electricity grid where the project will be located. This is because a power plant offset project could potentially displace any other plant that would serve the customers on that grid. Since the end-users are physically bound to using power from that grid, the offset project cannot offset a plant on another grid in the same country or other administrative region. This matters because emissions from new power plants may differ substantially from one grid to another depending on the resources available (for example, presence of hydro resources or access to natural gas pipelines). In some cases, grid regions may be clearly defined by remoteness and lack of interties to other grids (Roy et al., 2002; Winkler et al., 2001). In cases where interties do exist, defining the grid region may depend on other criteria, such as whether or not a competitive wholesale power pool exists, and the capacity of the interties to carry electricity (see Lazarus, Kartha, and Bosi, 2000 for a discussion of this issue). Fuel supply networks (access to gas pipelines) are another factor to consider.

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[9] Mandatory standards may dictate the eligibility of a project but the baseline performance standard may be different.

2.1.4 Biophysical (Transboundary) Region

In land use change projects, biophysical characteristics may define a project boundary that cuts across administrative and infrastructure networks. Agro-climatic, agro-ecological or ecological zones may be used to characterize regions with similar biophysical characteristics. For example, in the United States, a hierarchical system of ecozones was established in 1992, which maps zones as small as 10 acres in some cases by their common vegetation soil types, climate, etc. (Bailey et al. 1994). Similar classification systems exist in other temperate and tropical countries, which could form the basis for a biophysical characterization of land use.

Biophysical regions may be disturbed by human interference. Deforestation, for instance, is often accelerated by access to forest areas, and roads and river networks facilitate increased deforestation and provide easier access to forestland. Deforestation rates are often much higher along roads and river valleys and diminish as one moves away from them (Brown, Masera, and Sathaye, 2000). Historical rates of change will thus vary by spatial coordinates of the reference area.

2.1.5 Generic

Another approach would be to set geographic zones within which emissions rates for reference activities may be estimated using a generic expression. Input factors that contribute to emissions rates would be relatively uniform over this region. This would result in a set of performance standards differentiated by a few discrete input criteria. One could use different tiers to calculate baseline emissions following the approach adopted by the IPCC for estimating emissions levels for the national GHG emissions inventories.

For example, methane emissions from rice production may be expressed as a function of the annual harvested area, and a seasonally integrated emissions factor that depends on water management regime, ecosystem, and other conditions such as organic amendments (IPCC, 2000). Although the generic expression is the same, the emissions factors vary with the different inputs to rice cultivation resulting in a global expression but location specific methane emissions performance standards.

Similarly, methane emissions from animals may be expressed as a function of the gross energy intake, which in turn depends on animal live and mature body weight, and daily weight gain among other inputs. Simplified methods (referred to as Tier 1 methods in IPCC documents), on the other hand, make this expression simpler and the emissions factors (kg/head/yr) differentiate between different types of animals by geographic regions. Similarly, either a Tier 1 or Tier 2 (i.e., more detailed and sophisticated) approach may be used to set GHG performance standards depending on the availability of data and the size of the project. Smaller size projects in regions or countries with limited data may be deemed suitable for a Tier 1 approach, and others for a Tier 2 approach. Usually, this approach would be applied to projects whose spatial boundaries are determined by physical factors.

3. Setting the Temporal Period for Reference Activities

Estimating the emission rates of activities that a project may offset suggests the need to determine the reference activities that will likely occur in the future. Relying on projections of future activities and their emissions, however, can lead to large uncertainties in the projected performance standards. Activities may not occur as foreseen or the emissions rates of those activities may differ from what is expected.

An alternative approach is to use “recent” activities to estimate the emissions rates of activities likely to occur in the near future. This approach overcomes the uncertainty of relying on projections since the historical data are observable, whereas the GHG performance of near-future activities can only be estimated. Another advantage is that performance standards based on projections may be more susceptible to deliberate “gaming,” which will not be the case with recent activities. The approach to use recently completed activities, however, begs the question: what defines “recent?”

3.1 Defining the Temporal Period for Reference Activities

To gain insights in determining the time period to use in defining “recent,” we assessed the results from data analyzed for several electricity grids in India, South Africa, Guatemala, and the US (Sathaye et al., 2003, Roy et al 2003, Winkler et al, 2001). The electricity sector was chosen since data are readily available for many grids during the past decade, they permit testing for baseline activities that include multiple energy sources or demand management activities, and electricity sector policies and their impact on fuel and technology choices are relatively well known. In the case of power sector and industry projects, we refer to the average emissions rates of recently built plants as “build margins.” An *n*-year build-margin emissions rate would then consist of the total emissions divided by the total output of reference activities over the course of one year but that were brought on line during the previous *n* years. For example, the 1999 3-year build margin of power plants in a given area would consist of the total 1998 GHG emissions from all plants commencing operation between 1996 and 1998 divided by the total megawatt-hours produced in 1998 by these same plants.

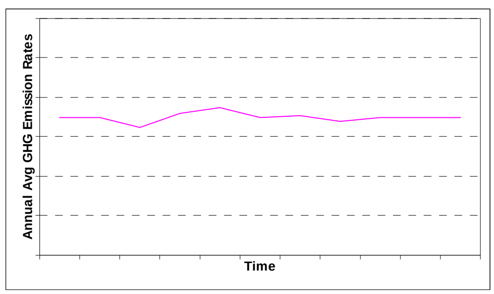
Although we use the power sector for this example, the concepts could be applied to projects from most other sectors as well. For example, the build margin in the manufacturing sector is analogous to that described above; it would consist of the average emissions rate of all plants built in the past *n* years manufacturing the same product (or delivering the same service) as the project. For other sectors, the average rates would not be build margins per se, but they may instead consist of *n* year average rates of change in the activity in question, such as changes in rates of deforestation. This approach is simplest in relatively homogeneous sectors, and more complicated in heterogeneous sectors, however, the concepts still apply.

We examined ten-year trends in annual build margins for the grids. Annual build margin refers to an average emissions rate of power plants that were brought on line in a single year. Constructing an *n-year* build margin has the advantage of smoothing out the annual emissions rate fluctuations that are caused by the different types of power plants that are built on a grid, or in an industrial setting the type and size of capacity that is added within a geographic region. Analyzing these values over the past ten years or so reveals trends that provide guidance to how many years worth of plants should be included in the build margin sample.

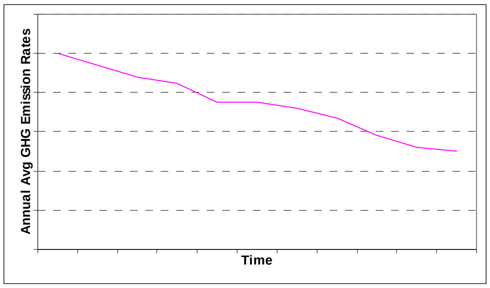
3.1.1 Implications of Patterns in Annual Build Margin Emissions

There are four possible trends in emissions that influence the choice of an appropriate temporal period for the setting of a GHG performance standard. A small graphic showing the average emissions of new activities in each year is included to illustrate each type of trend.

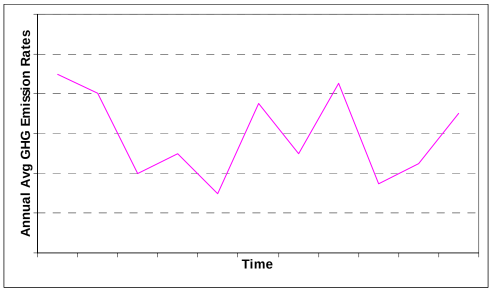
- Stable emissions rates: First, annual build margin emissions may be relatively stable over the period examined. This is likely to happen for a sector or region where one fuel source is dominant or no significant changes in technology have taken place. This is true, for example, of many grid regions in India and China, where coal provides the vast majority of the power generated. This may also be the case for entire industries, such as production of primary steel that depends heavily on one non-fungible fuel type. If this is the case, then the choice of the number of years will not have much impact on the resulting GHG performance standards, as long as the chosen years exhibit the stable emissions rate.



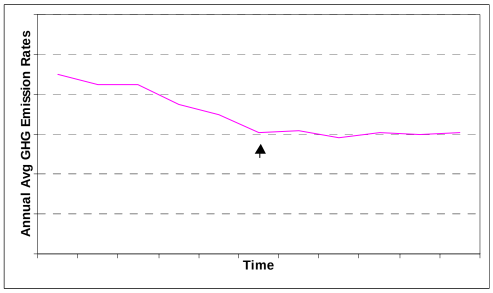
- Steady trend: Second, there may be a steady upward or downward trend in the incremental annual emissions rates. This would suggest using fewer years to calculate the build margin since including plants from too many years back would tend to overestimate (in the case of a significant downward trend) or underestimate the average emissions rate of plants expected to be built in the near future. Determination of the number of years selected could be driven by the degree of slope of the trend line (i.e., the steeper the slope the shorter the temporal period). Brown, Masera, and Sathaye (2000) cite an example from Chiapas, Mexico that shows the temporal variation in deforestation rates in Mexico from 1974 to 1996, which were used to derive a trend line of declining historical rates. Another example of such a trend is the steady decline in deforestation rates in Costa Rica that could have been used as a basis for setting future deforestation rates for the Protected Areas Project (Busch, Sathaye and Sanchex-Azofeifa, 1999).



- Scattered GHG emission rates: Third, there is the possibility that emission rates have not been stable and there has been no clear trend. This is likely to be the case for industries/regions with a greater diversity of resource options. Since the annual rates are random, this suggests that a greater number of years worth of plants may be necessary to obtain an average that is representative of the range of resource options for the industry in question. Scattered rates are most likely to occur in sectors where multiple fuel options exist for the activity in question. For example, in the power sector new plants could consist entirely of hydro or other zero-emission sources one year and only coal plants the next year.



- Clear break point: Fourth, there may be a clear break point in the plot of the annual emissions rates. In other words, over the course of a year or more, the trend in annual emissions rates may suddenly change to a significant degree. If a break point can be clearly identified, the break point year defines the most recent year that should be included in the build margin. For instance, the graphic shows that the downward trend that occurs during the first five time periods stabilizes from period 6 on. The changes in period 6 constitute a break point in the historical trend in emission rates. The causes and implications of break points are discussed in Section 3.2 below.



3.1.2 Empirical Analysis of the Build Margins on Grids in California and Guatemala

We examined data for the California and Guatemala electricity grids to gain insight into the use of n-year build margins as a way to determine appropriate temporal periods for performance standards that an administrator or project developer could use. Table 1 shows the data and performance standards for these grids.

As shown by the 1-year build margin values in Table 1, each grid exhibits characteristics of either a short-lived trend or a pronounced scatter (possibilities 2 and 3 above). For example, from 1989 to 1997 mostly new gas-fired plants were built for the California grid and the emissions rate varies in a narrower range with a declining trend line, but then the emissions rate drops to zero as only several small renewable units came on line. Other U.S. grids were also found to exhibit similar patterns through the 1990s, in part because the number of power plants built during this period was small and used a diverse mix of fuels.

As shown by the 1-year build margins, both grids exhibit variability from year to year in the average emissions rates of new plants going on line. Each grid had at least one year in which the power plants built that year had zero emissions while the maximum value ranged from 0.563 kgCO_2/kWh for California to as high as 1.039 kg CO_2 / kWh for Guatemala. What performance standard should be offered to a project developer in such a situation?

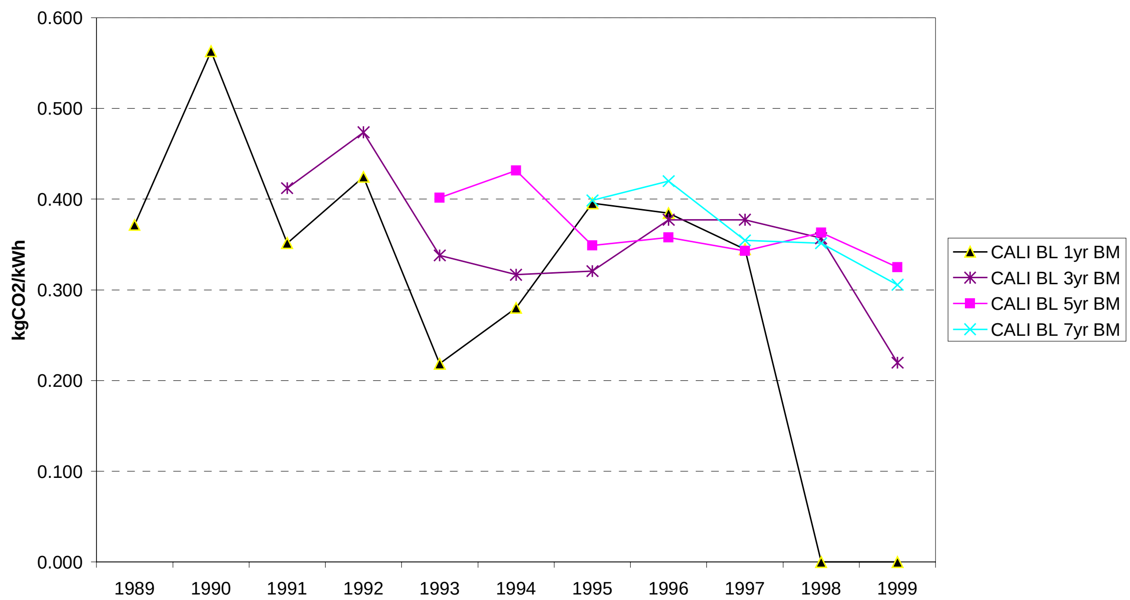
Including plants built in additional numbers of prior years makes the average more stable and more representative of the range of resource options available to the grid, e.g., the seven- and five-year build margins have less variation than the one-year build margin. When there is a high degree of scatter in the data, it is important to use a large enough time period to yield a representative mean. Using multiple years offers a way to smooth over annual fluctuations in the type and sizes of power plants that might be built in a given year.

Table 1. Number and Capacity of New Baseload Plants, and One-Year (Annual Average), Three-Year, Five-Year, and Seven-Year GHG Emissions Build Margins (BM) in kg CO2 / kWh

Subregion	Data	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
California	New Capacity, MW	1600	672	418	206	191	106	322	269	196	13	159	
	Number of Plants	42	24	11	5	6	4	3	4	4	4	10	
	One-yr BM (Avg Em Rate)	0.371	0.563	0.352	0.424	0.219	0.280	0.395	0.385	0.345	0.000	0.000	
	Three-Yr BM			0.412	0.474	0.338	0.317	0.321	0.377	0.377	0.357	0.220	
	Five-Yr BM					0.402	0.432	0.349	0.358	0.343	0.363	0.325	
	Seven-Yr BM							0.398	0.420	0.355	0.351	0.306	
Guatemala	New Capacity, MW						66	34	0	64	87	19	150
	Number of Plants						2	1	0	3	3	1	2
	One-yr BM (Avg Em Rate)						0.753	0.681	N/A	0.464	0.477	0.000	1.039
	Three-Yr BM								0.735	0.530	0.474	0.383	0.744
	Five-Yr BM										0.553	0.407	0.715
	Seven-Yr BM											0.475	0.718

Figure 1 compares the build margin trend lines for California in graphic form. This figure highlights the fact that performance standards based on multiple-year build margins will generally be subject to less fluctuation from year to year.

Figure 1. Comparison of Build Margins for the California Grid



One method to determine the temporal period is to compare how the various *n*-year performance standards derived for a given year (or set of years) fare in predicting the actual average emissions rates that manifested for that year or *n* subsequent years. Table 2a compares performance standards for the California grid calculated from years up to and including 1993 to subsequent build margins calculated from plants built in 1994 and beyond. For example, using only a one-year average (0.219 $kgCO_2/kWh$ in 1993) as a performance standard to project the 1994 value (0.280 $kgCO_2/kWh$) yields a difference of 0.061 $kgCO_2/kWh$ (i.e., the actual build margin for 1994 was 28% higher than the performance standard). The 1994-96 and 1994-98 build margins were 72% and 66% higher respectively than the performance standard based only on the 1993 plants. In this case, the mix of plants constructed in one year did not serve as a good predictor of what was built in subsequent years. Similarly, none of the performance standards were particularly accurate at predicting the average emissions rate of the plants built only in 1994. The 1991-93 and 1989-93 averages were off by –17% and –30% respectively.

The multi-year averages that include 1994 as well as subsequent years, however, correspond rather closely to the multi-year performance standards. These results are highlighted in Table 2. For example, the actual build margin of the plants built between 1994 and 1996 was only 12% higher than the three-year performance standard and 6% lower than the five-year performance standard. These results demonstrate that the need for multiple years' worth of plants to reflect the mix of resources on the grid applies prospectively as well as retrospectively.

Table 2. Differences between *n*-Year Performance Standards (PS) and *n*-Year Subsequent Build Margins (BMs) in kgCO2/kWh for the California Grid

				BMs for Subsequent Years		
				94	94 - 96	94 – 98
Absolute Differences				0.280	0.377	0.363
PS Years	93	1-yr PS	0.219	0.061	0.158	0.144
	91 – 93	3-yr PS	0.338	-0.058	0.039	0.025
	89 - 93	5-yr PS	0.402	-0.122	-0.025	-0.039
Relative Differences						
PS Years	93	1-yr PS	0.219	28%	72%	66%
	91 - 93	3-yr PS	0.338	-17%	12%	7%
	89 - 93	5-yr PS	0.402	-30%	-6%	-10%

Table 3 shows a statistical analysis of the set of results generated from performing the analysis shown in Table 2 from the data set of plants built for the California grid between 1989 and 1999. Instead of simply looking at the differences between hypothetical historical performance standards and the subsequent build margins before and after one year, this table shows an analysis of these differences over time. For example, columns 2, 3 and 4 in the table show the statistics about the difference between GHG emissions rates using 1-, 3-, and 5-years worth of data to project a GHG performance standard that is valid over the subsequent 5-year period. A performance standard was calculated from the average emissions rate of plants built in 1993 (1-yr PS) as well as all plants built between 1991 and 1993 (3-year PS) and all plants built between 1989 and 1993 (5-year PS). Then, both the performance standards and the subsequent 5-year periods whose emissions rates the performance standards are supposed to predict are each shifted forward by one year.[10]

The average of this set of differences is shown first. The closer the average difference is to zero, the better the performance standards from previous years predicted subsequent build margins. The standard deviation of these differences around the average provides an indication of the spread of the differences around the average. Next, 90% confidence intervals and prediction intervals are shown. The confidence intervals are shown not for any inferential value but rather to provide a sense of the spread in differences adjusted for the lower number of observations when using the larger performance standard and build margin intervals. The prediction intervals indicate how large a spread one would need to capture the next data point in the series at 90% confidence.

[10] This means, however, that for any given range of data, larger intervals for either the performance standards or subsequent build margins will reduce the number of possible observations. For example, if one were using a data set of ten years of annual build margins, there would only be one difference to calculate for a five-year performance standard compared to a subsequent five-year build margin (i.e., the average build margin of the first five years compared to the average of the last five years). However, a one-year performance standard compared to the following year's build margin would yield nine observations.

Table 3. Statistical Analysis of Differences in Estimated California Grid GHG Performance Standards (PS) and Subsequent Build Margin (BM) Emission Rates (1989-1999) in kgCO_2/kWh

	5-yr Subsequent BM Emissions Rate			3-yr Subsequent BM Emissions Rate			1-yr Subsequent BM Emissions Rate		
	1-Yr PS Col. 2	3-Yr PS Col. 3	5-Yr PS Col. 4	1-Yr PS Col. 5	3-Yr PS Col. 6	5-Yr PS Col. 7	1-Yr PS Col. 8	3-Yr PS Col. 9	5-Yr PS Col. 10
Avg Diff	-0.006	-0.038	-0.073	-0.026	-0.045	-0.053	-0.037	-0.116	-0.140
Std Dev	0.114	0.061	0.034	0.128	0.093	0.054	0.159	0.174	0.158
Conf Int ±	0.091	0.065	0.070	0.084	0.073	0.058	0.091	0.114	0.125
Pred Int ±	0.240	0.146	0.122	0.252	0.194	0.129	0.302	0.343	0.331

Column 2 shows that the average difference in the 1-year performance standard and the average build margin emissions rate for the subsequent 5 years over the 1989-2000 period is -0.006 kg CO_2/kWh, which increases to -0.073 kg CO_2/kWh using the 5-year performance standard. The standard deviation is lower in Column 4 than in Col. 2, indicating that while the average difference (mean) is larger, the data points are closer together. In other words, the result is not as accurate but it is more precise. The confidence and prediction intervals account for the variation in the number of data points and these values are tighter in Col. 3 compared to Col. 2, and the PI is tighter in Col. 4 compared to Col. 3. Although the intervals are narrower for the multiyear performance standards, the differences are relatively less pronounced than they are among the standard deviations.

Columns 5, 6, and 7 show a similar calculation in which the 1-, 3- and 5-year performance standards are used to project average emissions rates for the subsequent 3-year periods. The standard deviation, the confidence and prediction intervals all improve from Col. 5 to 6 to 7. The prediction interval is larger in each case than in the comparable 5-year cases (compare Columns 5 with 2, 6 with 3, and 7 with 4). The average difference, the standard deviation and the confidence interval are worse in this case than in two of the comparable 5-year cases (compare Columns 5 with 2 and 6 with 3), but not in the last case (compare Columns 7 with 4). As shown in the last three columns (8, 9, and 10), the use of the performance standards to predict the average emissions rate of only the following year results in less uniformity in the values of the indicators, and higher (poorer) values for all four indicators compared to the 5-year and 3-year cases.

The results show that there tends to be less variance in the differences between performance standards and subsequent build margins when longer time periods are used to calculate both. Thus predictive intervals will also generally be lower. The results of the analysis shown in both Table 2 and Table 3 suggest that a performance standard will not necessarily accurately predict the average emissions rate of displaced reference plants in a particular year, but it may provide a reasonable approximation of what plants would be built in the future during a relatively short period.

In contrast to the relatively steady five- and seven-year rolling averages exhibited by California's grid, the build margins for Guatemala's new power stations show a noticeable downward trend followed by an abrupt upturn in 2000 (Table 1). This is due to the commencement of operations at the San Jose coal-fired power plant. The relatively large size (120 MW) and high carbon intensity compared to other plants on the Guatemala grid had a tremendous impact on all of the averages. Presumably, now that facilities have been established to receive and process coal, it is all the more likely that coal-fired power plants may be constructed in the future (TWG, 2003). This may represent a real break point that leads to higher GHG performance standards from 2000 on. Similarly, a planned regional transmission line (known as SIEPAC) would constitute another break point since new power for distribution in Guatemala could come from any of the other five participating Central American countries thus broadening the resource base for future power needs. The different types of break points and their implications for setting performance standards are discussed below.

3.2 Break Points

Although the previous analysis suggests using multi-year build margins, in cases where a break point has occurred one may need to restrict the reference activities to those initiated since the break point. Generally, break points are driven either by policy changes or by autonomous changes in technology or the resource mix. The different types of break points are summarized in Table 4.

Another implication of break points is that if a break point has occurred recently, or is likely to occur in the near future, this may suggest the use of data taken from proposed near-future activities. However, one must be careful when using such data since the emissions rates and activity levels of proposed activities can only be estimated. In addition, it is not uncommon for proposed facilities or land-use projects to be aborted, even at relatively advanced stages of implementation. Consequently, any performance standards based on the use of projected near-future activities are subject to a high degree of uncertainty.

Table 4. Types of Trend Line Break Points

Break Point Category	Subcategory	Examples
Policy Driven	Fuel	Change in subsidies or taxes affecting a specific resource.
	Privatization/ Deregulation	Privatization or deregulation in the manufacturing or electric power sectors.
	Environmental	Clear air regulation that limits use of certain resources or renders them more expensive. Passage of laws that restrict logging or development in certain areas.
	Technology-specific	Subsidies promoting particular technologies, such as renewables or CHP.
Autonomous	Fuel Supply	Extension of natural gas pipelines, discovery of new resources, saturation of hydro resources, or depletion of economically recoverable resources of a given fuel.
	Technology	Technological developments significantly affecting the GHG emissions characteristics of certain activities, e.g. elimination of HFCs from a given manufacturing process or improvement in wind turbine design.
Market Integration (change in spatial parameter)	N/A	Integration of markets through international accords or improved transportation infrastructure. Connection between previously isolated electricity grids to a degree that they must now be treated as a single grid.

3.2.1 Policy-Related Break Points

Examples of policy changes that may have an effect on the resource mix include policies that restrict the use of certain resources or otherwise affect their price and availability. For example, this could consist of a new subsidy for coal production that results in lower market prices for coal. The privatization or deregulation of a sector may also result in a technology fuel mix shift. Power sources at the margin have changed drastically in Guatemala since the restructuring of its power sector. Until 1986, the power sector in Guatemala was completely state run. The state power company focused on developing Guatemala's indigenous power supply, which consists chiefly of hydropower (Dorion, 2003). The privatization of power supply in Guatemala resulted in a sharp increase in investment of large reciprocating engines using diesel fuel, whereas prior to that, the bulk of the power serving the Guatemalan main grid was from hydro stations. This is a common phenomenon when private investors begin to invest in generation, since private investors will seek to minimize their risk by developing plants with low capital costs and short construction lead times.

Environmental regulations are another example of a policy-related break point. Environmental policies that could affect the price and availability of certain resources include air pollution regulations that might raise the cost of using certain fuels or wildlife habitat protection policies that impede certain uses of land in a given area. Policies designed to favor particular types of technologies could also result in break point for build margins. Examples of these may include subsidies for certain kinds of renewables, such as production credits for wind farms, or tax breaks for companies installing CHP units.

3.2.2 Autonomous Changes in Fuel Supplies and Technologies

A second type of break point may occur where there are autonomous changes in fuel availability or technology development. One example that is likely to have an effect on many regions in the foreseeable future is the extension of natural gas supply networks. The extension of a natural gas pipeline into another region may significantly shift the fuel mix of future manufacturing, power generation, and space heating toward the use of natural gas. In contrast to availability of a new fuel source, there is also the possibility that an existing power source may become constrained. This could occur on grids, such as those in Brazil, that have relied heavily on hydropower and where hydro resources are reaching saturation. Further expansion on such a grid will require increasing exploitation of other fuel sources.

Alternatively, autonomous technological change may occur as new technologies become available or breakthroughs are achieved in the efficiencies of existing technologies. Examples of the former might include periods in the past when combined cycle gas turbine technology and combined heat and power were emerging.

3.2.3 Market Integration

Finally, another circumstance that affects resource and technology availability, albeit in another way, is the integration of markets that were previously isolated or constrained. Market integration may affect the spatial parameter of the reference activities since the project's outputs may now effectively displace a similar activity anywhere in the market region. It may also provide access to more efficient technologies for some uses. A change in the spatial parameter should lead to a reevaluation of the temporal criteria since the universe of reference activities may differ significantly with the increased geographic scope. In cases of recent market integration, the temporal period should extend no further back than the point of integration.

4. Conclusions

This paper assesses spatial boundary and temporal period considerations, two key criteria in the setting of GHG performance standards for mitigation projects. Considerations of physical and anthropogenic factors determine whether reference activities should be global or confined to national boundaries and other administrative regions; infrastructure based boundaries; or biophysical (transboundary) regions. If a generic formulation can be devised, it may not be necessary to examine specific reference activities at all. Mature, capital-intensive technologies are likely to have similar energy intensities globally, which can be used to set global GHG performance standards. Administrative zones, particularly national boundaries, may dictate the geographic scope for technology projects affecting GHG emissions. A well-defined electricity grid would serve as an appropriate boundary for setting electric power sector baselines. A biophysical basis that cuts across administrative zones may be appropriate for LUCF projects. Finally, agricultural practices may be amenable to the use of generic expressions that define baseline emissions.

The temporal period for setting a GHG performance standard may be decided by examining the trends in historical emissions rates. Statistical analysis of emissions rates shows that in the case of a stable trend almost any period within reason could be used to determine the GHG performance standard. However, when a steady downward or upward trend is evident, the use of a recent few years to set a GHG performance standard would avoid using too low or high values from earlier records in a historical period. For a scattered set of values, emissions rates should be averaged over several years to capture a representative mean. Finally, where there is a clear break in a historical trend, it would be important to determine when the break occurred, why it occurred, and whether the change is likely to be stable or not. This would have to be done through a careful analysis of the causes of the break in trend. A break due to a prolonged drought may not indicate a permanent change in the trend, but one caused by a technological breakthrough might be an indicator of a new emerging trend. In this case, the temporal period should extend back no further the appearance of the break point.

Performance standards based on too short a time frame are likely to perform poorly as predictors of the average emissions rates of subsequent activity, except in the case of a stable trend. The greater the variety of technologies and fuels available to perform a given activity, the larger is the chance that annual average emissions rates will fluctuate significantly. As an example, statistical analysis of California electricity grid data suggests that the use of multiyear averages of emissions rates help to smooth over annual fluctuations in rates and narrow the range in predicted values.

Spatial and temporal criteria are interactive and can change over time. As markets get integrated, reference activities may have to span beyond current spatial boundaries and temporal periods, and integration may also mean that new technologies are introduced and older data on emissions rates are no longer valid, or are of limited use.

Finally, administrators of GHG mitigation programs need to ensure that the spatial boundaries are broad enough to include all relevant reference activities, and the variation in emissions rates within the boundary are reflected in the GHG performance standard. The temporal period should be long enough to overcome episodic fluctuations in emissions rates, but short enough to ensure that the reference technologies and fuel choices are reflective of current and near future emissions rates.

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References

Bailey, R.G., Avers P.E., King T., and McNab W.H., eds. 1994. *Ecoregions and Subregions of the United States (map)*. Washington, DC, U.S. Geological Survey. Scale 1:750,000; colored. Accompanied by a supplementary table of map unit descriptions compiled and edited by W.H. McNab and R.G. Bailey. Prepared for the U.S. Department of Agriculture, Forest Service.

Brown S., Masera O., and Sathaye J., 2000. Project-Based Activities. Chapter in *Land use, Land-use Change, and Forestry*. Eds. R. Watson, I. Noble, B. Bolin, N. Ravindranath, D. Verardo and D. Dokken. Printed by Cambridge University Press for the Intergovernmental Panel on Climate Change.

Busch C., Sathaye J., and Sanchez-Azofeifa G., 1999. *Lessons for Greenhouse Gas Accounting: A Case Study of Costa Rica's Protected Areas Project.* LBNL 42889.

Dorion, K., 2003. Standardized Baseline Approach to the Guatemalan Electricity Sector. unpublished paper, Center for Sustainable Development in the Americas

EIA [Energy Information Administration/U.S. Dept. of Energy], 2002. Annual Energy Review 2001. http://www.eia.doe.gov/emeu/aer/txt/stb0608.xls

IEA [International Energy Agency], 2002. Beyond 20/20 Database: Energy Balances of OECD and non-OECD Countries. Paris: IEA

IPCC [Intergovernmental Panel on Climate Change], 2000. Good Practice Guidance and Uncertainty Measurement in National Greenhouse Gas Inventories.

Kartha, S., Lazarus, M., and Bosi, M., 2002. Practical Baseline Recommendations for Greenhouse Gas Mitigation Projects in the Electric Power Sector. OECD/IEA Information Paper. http://www.iea.org/envissu/ghgmit.pdf

Roy, J., Das, S., Sathaye, J., and Price, L., 2001. Potential Multiproject Baselines in the Power Sector in the Eastern Region of India. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-48242C

Sathaye, J., Murtishaw, S., Price, L., Lefranc, M., Roy, J., Winkler, H., and Spalding-Fecher, R., 2004. Multiproject Baselines for Evaluation of Electric Power Projects. *Energy Policy* 13 (11): 1303 - 1317.

TWG [TECO Wholesale Generation], 2003. "Our Projects: San Jose Power Station." http://www.tecowholesalegeneration.com/TWGSanJose.cfm

U.S. DOE, 2003. Enhancing the Department of Energy's Registry of Greenhouse Gas Emissions and Emission Reductions. http://www.pi.energy.gov/enhancingGHGregistry/index.html

U.S. EPA, 2003. Emissions & Generation Resource Integrated Database (eGRID) version 2.01. http://www.epa.gov/cleanenergy/egrid.htm

Winkler, H., Spalding-Fecher, R., Sathaye, J. & Price, L., 2001. Multi-project baselines for potential Clean Development Mechanism projects in the electricity sector in South Africa. *Journal of Energy in Southern Africa* 12 (4): 449-457